Escherichia coli O157:H7

Issues and Ramifications

Executive Summary

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USDA:APHIS:VS
Centers for Epidemiology and Animal Health
555 South Howes
Fort Collins, Colorado 80521

To
"*E*
please contact:

Centers for Epidemiology and Animal Health
USDA:APHIS:VS
555 South Howes, Suite 200
Fort Collins, Colorado 80521

Area Code (303) 490-7812

Executive Summary

Escherichia coli O157:H7 -- Issues and Ramifications

This document summarizes findings presented in the report entitled "*Escherichia coli* O157:H7 -- Issues and Ramifications[1]." The primary purpose of that report is to help define the role of cattle as a source of *E. coli* O157:H7 in food products. Although different modes of transmission from cattle to humans are discussed in the report, it concentrates on the vehicle most frequently implicated in human disease outbreaks, ground beef. This summary is divided into four sections: (1) Why the interest in *E. coli* O157:H7?, (2) What is known about *E. coli* O157:H7 in cattle?, (3) Do production and consumption patterns for ground beef offer any additional insight into *E. coli* O157:H7?, and (4) Future directions.

Why the interest in *E. coli* O157:H7?

Escherichia coli O157:H7 (O157) was first identified as a human pathogen capable of causing foodborne illness in 1982. However, the public was generally unaware of the existence of O157 until a decade later. In late 1992, an outbreak associated with the consumption of undercooked hamburgers began in Washington state. The more than 600 illnesses and the subsequent deaths of 4 children were publicized throughout the country. In addition, evidence suggesting that the frequency of O157 illness in humans is increasing has heightened concern. Of the 32 outbreaks reported in the U.S. from 1982 through 1993, 13 occurred in 1993.

Human illness associated with O157 is infrequent in comparison to illness associated with some other foodborne pathogens such as *Salmonella*. However, the range in severity of clinical illness and the potential for debilitating complications and death makes O157 a noteworthy food safety issue. The abdominal cramping and bloody diarrhea typical of O157-associated disease result from toxin production and subsequent destruction of the mucosal lining of the colon. In most patients, the disease is self-limiting. However, a small percentage of O157 cases progress to hemolytic uremic syndrome (HUS) and/or thrombotic thrombocytopenic purpura (TTP). The elderly and children less than 5 years old are at highest risk of developing these complications. Such cases may result in kidney failure or death.

Although not definitively established, it is believed that O157 inhabits the lower intestine of cattle and is shed in the feces. Human infection with O157 occurs primarily through ingestion of food contaminated with fecal material. Another recognized source of infection is O157-contaminated water. Human-to-human and calf-to-human transmission have also been documented.

Although O157 is one of many serotypes of a common and ubiquitous bacteria, a unique characteristic of O157 is the organism's hardiness. It can survive for extended periods in water, meat stored at subfreezing temperatures, acidic environments, and soil. The organism is, however, destroyed by thorough cooking or pasteurization.

A variety of foods have been implicated in O157-associated illnesses. Of the 24 outbreaks associated with foods, 17, or 71 percent, have been linked to bovine products. Contaminated ground beef was associated with 12 of the outbreaks, raw milk and roast beef with 2 each, and 1 with hot dogs containing beef. Cross-contamination of other foods, including apple cider,

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[1] References are not given in this summary document but may be found in the complete version of "*Escherichia coli* O157:H7 -- Issues and Ramifications."

vegetables, and mayonnaise, by manure or meat products has been confirmed or is suspected in the seven other foodborne outbreaks.

Although not directly linked to human illness, several other meat and poultry products have been sampled for O157. In addition to beef, the organism has been isolated from veal kidneys, poultry, pork, and lamb. However, cross-contamination of these meat products is considered likely. To date, farm-level testing in the U.S. has concentrated on cattle. As a result, the status of O157 in other food animal species is not known.

There is no definitive evidence of a geographic pattern of human O157 cases. However, a 2-year study concluded that a significantly higher percentage of stool samples were O157-positive from hospitals in the northern and western U.S. than in the southern part of the country.

Both O157 sporadic cases and outbreaks have a definite seasonal pattern. The four largest studies in the U.S. have revealed that at least 67 percent of sporadic cases occurred between May and September, with a peak in July and August. Of all U.S. outbreaks associated with O157, 88 percent have occurred from May through November.

At least 16 countries on 6 continents have documented human cases or bovine isolates of O157, indicating the widespread presence of the organism. Outside of the U.S., most occurrences of O157 illness have involved sporadic cases; only Canada and the United Kingdom have reported outbreaks. As in the U.S., cases have generally peaked in the summer and fall months.

What is known about *E. coli* O157:H7 in cattle?

The epidemiologic link between human O157-associated illness and products of bovine origin has raised many questions concerning the occurrence of the organism in the cattle population. Beyond the observation that O157 is not known to cause clinical disease in cattle under natural conditions, little is known about the on-farm ecology of the organism. Analysis of O157 on-farm studies indicates that virtually all types and breeds of cattle should be viewed as potential sources of O157 contamination. Changes in various management practices which may have allowed or enhanced the ability of the O157 organism to inhabit the gastrointestinal tract of cattle are under investigation. At present, no definitive cause and effect relationships have been established.

The only nationwide on-farm study completed to date focused solely on preweaned dairy heifers (National Dairy Heifer Evaluation Project, NDHEP). Other studies, primarily in Washington state, have looked at adult dairy and beef cattle, as well as dairy calves. All studies found relatively low percentages of cattle shedding O157 (animal prevalence), generally less than 1.0 percent. In the one study which has looked at beef premises, the prevalence of shedding among adult beef cattle was slightly higher than has been found among adult dairy cattle. In all studies, dairy heifers and calves generally had a higher prevalence of O157 shedding than did adult dairy cattle.

The prevalence of herds with O157 (herd prevalence) has generally been higher than the overall animal prevalence of O157. To date, in studies of premises not associated with O157 tracebacks, 27 (2.4%) of 1,139 dairies and 4 (16.0%) of 25 beef premises have been culture-positive for O157. However, research suggests that the greater the number of animals sampled on a premises, the greater the likelihood of finding that premises positive for O157. Because there have not yet been many studies that sampled more than a few animals per premises, it is probable that true herd prevalence in the U.S. is much higher than has been found to date. In addition, the NDHEP found no geographic patterns or regional differences in herd prevalence or overall animal prevalence.

Most of the initial prevalence studies have been based on one-time fecal sampling. Consequently, little is known concerning the carrier status of individual animals. Preliminary evidence does, however, suggest that cattle transiently or sporadically shed O157 in their feces and that the excretion period ranges from hours to weeks. These observations are important in that on-farm sampling of individual animals may not be an accurate reflection of the shedding status of animals entering the slaughter facility.

Evaluation of seasonal patterns in the detection of O157-positive animals is inconclusive. One Washington state study found the isolation rate of O157 to be highest during the summer months, reaching a peak in September with 13 positives per 1,000 samples. This seasonal pattern was observed in both years of the study. These results are of interest in light of the seasonal pattern evident in human O157-associated illness. In contrast, no seasonal pattern could be established from the NDHEP, which had a much larger sample size and in which roughly equal numbers of dairy calves were sampled during each calendar month. The conflicting results may be attributable to differences in age, since the Washington study included adult cattle whereas the NDHEP did not.

No evidence was found of significant O157 transmission between dairy cattle in the NDHEP. Positive and negative herds were compared with respect to calf contact with older cattle and time spent by calves in maternity pens. Prevalence of O157 among preweaned dairy calves having contact with older heifers was similar to that of calves having no contact. No significant difference in herd prevalence was identified between herds that did and those that did not permit contact among calves and older animals. The length of time calves remained in the maternity area was likewise not shown to affect the prevalence of O157.

Various management and feeding practices are being examined for possible links to the presence of O157. Several practices have been found to have either a positive or negative association with the presence of O157 (Table 1). Whether or not these associations are relevant to the colonization of cattle with O157, or if cattle are even truly colonized by O157, is not yet known.

Feeding subtherapeutic levels of antibiotics to cattle to improve feed conversion and rates of weight gain is a management practice that has raised concerns. No evidence exists to suggest that O157 has acquired resistance to antibiotics. In fact, the opposite is true; most O157 organisms are susceptible to a variety of antibiotics. In addition, the use of antibiotics in cattle feed has been reduced since 1985. Current estimates indicate that only about 10 percent of all feed produced for beef cattle in the U.S. is formulated to contain antibiotics.

There is speculation that the use of ionophores, a class of antibiotics which is currently fed to certain types of cattle, may have allowed or enhanced the ability of O157 to become established as part of the intestinal microflora of cattle. The approval and subsequent adoption of ionophores for feedlot diets of cattle in the mid- to late-1970's roughly coincides with the identification of O157 as a foodborne human pathogen. Ionophore products are currently reported to be used in the diets of more than 90 percent of feedlot and farm-fed cattle and in less than 50 percent of replacement heifers and beef and dairy calves. Ionophores have been shown to inhibit gram-positive organisms in the rumen and, therefore, may allow the increased proliferation of gram-negative organisms such as *E. coli*. One study has reported that dairy farms feeding ionophores in grain had a higher O157 prevalence in calves than did farms not feeding ionophores. However, a follow-up study found no such association.

Other management practices can result in increased levels of stress in cattle. Weaning, abrupt changes in dietary composition, fasting, shipping, disease, or changes in immunologic status can predispose animals to shifts in the normal microflora of the gastrointestinal tract. It has been

suggested that these shifts may result in increased numbers and/or increased shedding of O157 in cattle.

Dietary stress may be an especially important factor. The first notable dietary stress in an animal's life is weaning. One study of dairy calves revealed that the prevalence of O157 in postweaned calves was three times higher than among preweaned calves. Studies in nonbovine species have shown increased numbers of *E. coli* organisms in the intestinal tract post-weaning. *E. coli* numbers have also been shown to increase in the gastrointestinal tracts of adult animals and birds following starvation or abrupt dietary changes. Cattle are usually held off feed in the hours prior to slaughter.

Transportation provides another source of stress for livestock and may be a critical factor prior to slaughter. There is some indication, based on a recent survey of packers, that transport distances to slaughter are greater for cows and bulls than they are for fed steers and heifers and have increased over the past 10 years. Whether greater transport distance leads to increased stress is not known, but greater time in transport and holding has been shown to increase rates of infection of cattle with organisms such as *Salmonella*.

Although there has been speculation that mastitic cows may be a primary source of O157 contamination, no evidence exists to single out this particular subgroup of the cattle population. No O157 was identified in more than 500 cases of coliform mastitis in 2 separate 1993 studies conducted in California and Pennsylvania. In addition, patterns in the recorded cases of clinical mastitis identified at slaughter do not correspond to trends in outbreaks and sporadic cases of human O157-associated illness. Neither the number nor the rate of mastitic cows at slaughter increased between 1983 and 1992.

Similarly, no evidence has been presented which argues for focusing on nonambulatory cows (downer cows) as a major source of O157. The hypothesis that possible increased antibiotic usage in nonambulatory cattle could help to select for O157 or allow O157 to more readily colonize such animals does not seem highly plausible since O157 is itself susceptible to most antibiotics. However, increased stress as a result of the downer condition may increase the likelihood of shedding O157 if it were present. A current Food Safety and Inspection Service study of nonambulatory cattle should help define any relationship between O157 and such animals.

Do production and consumption patterns for ground beef offer any additional insight into *E. coli* O157:H7?

Contaminated ground beef has been the most frequently identified vehicle for O157 in human disease outbreaks. The introduction of O157 may occur at any point along the entire production to consumption continuum. Therefore, changes in the continuum over the past decade need to be identified and examined for potential impacts on ground beef contamination or increased human exposure to O157-contaminated ground beef.

Relative proportions of different types of cattle slaughtered in the U.S. have changed little since 1980. Steers and heifers accounted for approximately 80 percent of cattle slaughtered, cows 18 percent, and bulls 2 percent. Calf slaughter was minimal when compared with cattle slaughter and meat from calves generally does not go into ground beef. Production for all types of cattle continued to concentrate geographically into fewer and larger herds, particularly in dairy and cattle feeding operations.

Marketing of all types of cattle for slaughter has changed somewhat over the same time period. Currently on a national basis, greater percentages of cattle are being sold directly to packing

establishments rather than being marketed indirectly through public markets. In 1980, 88 percent of steers and heifers and 35 percent of cows were sold directly, but by 1990 those figures were 94 and 40 percent, respectively.

Slaughter facilities have become larger and more concentrated geographically, particularly in the Great Plains region. In 1992, 90 percent of all fed steers and heifers were slaughtered in only 33 plants, as compared to 90 plants in 1983. In 1992, 90 percent of cows were slaughtered in 68 plants, down from 152 plants in 1983.

Once cattle have been slaughtered, ground beef production flows through a variety of processing and distribution channels (Figure 1). Ground beef is produced directly in some slaughter plants from varying combinations of cuts and trimmings produced in-house, purchased trimmings, and domestic and imported boneless manufacturing-grade beef (BMB). Ground beef is also produced by grinders and retailers who purchase carcasses, boxed beef, bulk trimmings, and/or coarse ground trimmings from slaughter plants, other grinders, and/or distributors. There are currently 2,965 grinders in the U.S., of which less than 900 slaughter cattle. In 1992, there were 30,700 supermarkets with in-house meat departments.

The sale of fed beef by packers in the form of boxed beef rather than carcasses has steadily increased over the past 20 years and has had an impact on the production and distribution of ground beef. Boxed beef is sold as vacuum-packaged primal and subprimal cuts from which much of the bone and excess fat has been removed. This has meant that more trimmings from fed cattle are produced centrally at the slaughter plant rather than locally at the grinder or retail level.

The percentages of ground beef derived from individual types of cattle can be estimated as a national average for a given time period. In 1980, steers and heifers accounted for 56 percent of domestic raw product going into ground beef, cows for 36 percent, and bulls for 8 percent. By 1992, these percentages had changed only slightly to 58 percent steers and heifers, 34 percent cows, and 8 percent bulls. Boneless manufacturing beef imports also remained stable over the last decade, comprising approximately 15 percent of the total U.S. ground beef supply.

Although the proportion of cattle types slaughtered varies regionally, ground beef formulation does not. The formulation of ground beef is based largely on fat content. Lean meat from cows and bulls and lean and fat trimmings from fed steers and heifers can be shipped to various locations and then mixed to produce the final ground beef product.

The composition of ground beef in terms of the sources of raw product (lean and fat) appears to be independent of the production and distribution channel through which it passes. Any given pound or patty of ground beef can contain any combination of domestic cow meat, domestic fed beef, and/or imported BMB, regardless of the channel through which it was produced.

Per capita ground beef consumption (net disappearance) has increased since 1980 but is still below mid-1970 levels. Both the proportion of people that consumed ground beef in the form of hamburgers and the amount consumed increased in most age groups, including those at highest risk for O157-related illness, young children and the elderly. There was a corresponding increase in food expenditures outside of the home during the same time period. In 1992, fast food hamburgers accounted for about 47 percent of fast food sales, or 15 percent of all hotel, restaurant, and institution (HRI) sales.

Ground beef consumed in HRI settings, especially fast food establishments, is purchased primarily from grinders in the form of patties. Retail sources of ground beef are more evenly distributed among cow packers, fed beef packers, grinders, and trimmings produced in-house. This information

along with the apparent increased consumption of hamburgers in HRI settings appears to indicate that a greater proportion of ground beef is now flowing through the channel from grinders to HRI's than during the early 1980's.

Future directions

• Would a geographic pattern in the number of O157 cases in humans tell something about O157 prevalence in cattle?

It is unlikely that any geographic pattern of human disease would reflect a geographic variation in the source of the O157-contaminated ground beef. In many cases the location of consumption of ground beef is not related to the original location of the sources of that ground beef nor to the potential sources of O157 contamination. Cattle that go into ground beef production may be moved great distances in the hours prior to slaughter, lean and fat trimmings may be shipped some distance prior to final grinding and mixing, and the final product may in turn be widely distributed.

• How can we explain the seasonality of human cases and outbreaks associated with ground beef?

The seasonality of cases and outbreaks associated with ground beef might be a reflection of any one or a combination of factors. First, there may be greater shedding of O157 by cattle during warmer months of the year, which may lead to increased contamination of ground beef during these months. Second, consumption of ground beef is higher during warmer months (summer barbecues, picnics, etc.). Third, there may be a greater likelihood of temperature abuse and/or less thorough cooking of ground beef during these months.

• Is there a particular channel in the ground beef production continuum that is associated with an increased risk of O157 contamination?

Ground beef intended for both retail and HRI can pass through various channels which may include a number of different steps. Although additional handling creates more opportunities for cross-contamination, no one channel can be singled out at this time as posing a greater risk.

• Should the goal be to eradicate O157 on the farm?

It does not currently appear feasible to target on-farm eradication of O157 for the following reasons: the lack of knowledge about the ecology of O157, the widespread geographic distribution of the organism, the fact that O157 has been found in both beef and dairy cattle, and the difficulty of identifying infected animals because of the likelihood of sporadic shedding and the absence of clinical disease. Since the risk of O157 illness cannot be eliminated at this time, it must be managed.

• How can the risk of O157 illness best be managed?

A general approach to manage the risk of O157 illness attributable to ground beef is: (1) to reduce the level of O157 on the farm, and (2) to better understand different channels of the ground beef production system and use this knowledge to identify critical points at which intervention would be most effective. To gain a better understanding of the system, specific questions that need to be addressed include: (a) how does the number of steps involved in the production of ground beef affect the risk of contamination?, (b) how does the risk change as ground beef moves through the system?, and (c) what is the volume of ground beef that flows through the various channels? If it

is possible to identify one or two points along the continuum that can be associated with an increased risk of O157 contamination, then research can be focused on those specific channels.

- Where should attention be focused?

Attention should be focused on what occurs just prior to slaughter. Because shedding of O157 may be sporadic, cattle that test O157-negative on the farm may test positive just prior to slaughter. This is especially plausible in light of the many stress factors to which cattle are subjected between leaving the farm or feedlot and slaughter. Although it is not known if cattle that are not shedding O157 at the time of slaughter can be a source for ground beef contamination, animals which are shedding can be a factor in such contamination. Thus, individual cattle should be followed and sampled at various points after leaving the farm. Sampling at the auction barn, feedlot, after unloading at the slaughter plant, and immediately before slaughter may provide valuable information about shedding patterns. The cleanliness of animals entering the slaughter facility is also an important consideration. Contamination of the hide and haircoat with mud and feces may provide O157 with an additional mode of entry into the slaughter facility via either culture-positive or culture-negative animals.

- What other types of preharvest research should be recommended?

Research should concentrate on the ecology of O157 in the gastrointestinal tract of ruminants, specifically to assess the effects of stressors such as dietary changes and movement of animals. The ecology of O157 in the farm environment also needs further research. Since previous studies of management factors, such as the use of ionophores, have not been definitive, further work is needed to address the effects of management factors on the prevalence of O157. Competitive exclusion, the administration of protective intestinal microorganisms known as probiotics, should also be evaluated as an intervention strategy. Probiotics can protect poultry from colonization by human enteropathogens, including O157. Results of studies on the use of probiotics in cattle have been variable. None of the currently available probiotic feed supplements for cattle marketed in the U.S. has met the regulatory requirements for demonstration of prophylactic or therapeutic claims.

- What about postharvest research?

Emphasis should be placed on identifying and monitoring where and how contamination occurs. The Hazard Analysis and Critical Control Point (HACCP) system should continue to be developed and implemented as a preventative food safety assurance system. HACCP principles should be applied not only at slaughter and grinding facilities but also at other points along the continuum including shipment between locations and storage. The intent would be to ensure that a product leaving a certain phase of production or location is as safe or safer than when it entered.

- What about tracebacks?

Tracebacks have been proposed as an important component of a food safety agenda. In the case of O157, tracebacks could provide valuable information about on-farm factors and production processes associated with the organism, as well as about the ecology of O157. However, from an immediate disease prevention perspective, tracebacks would currently be of uncertain value. Not enough is known about the ecology of O157 in cattle to implement prudent, on-farm measures to prevent future contamination. Tracebacks involving ground beef would be especially difficult to carry out to the farm level with a high degree of precision. Even given a highly dependable system of individual animal identification, the complexity of production and distribution channels for ground beef tends to make the determination of individual animal contributions to any given pound of product a difficult process.

Table 1. Association of *E. coli* O157:H7 with Selected Management Practices*

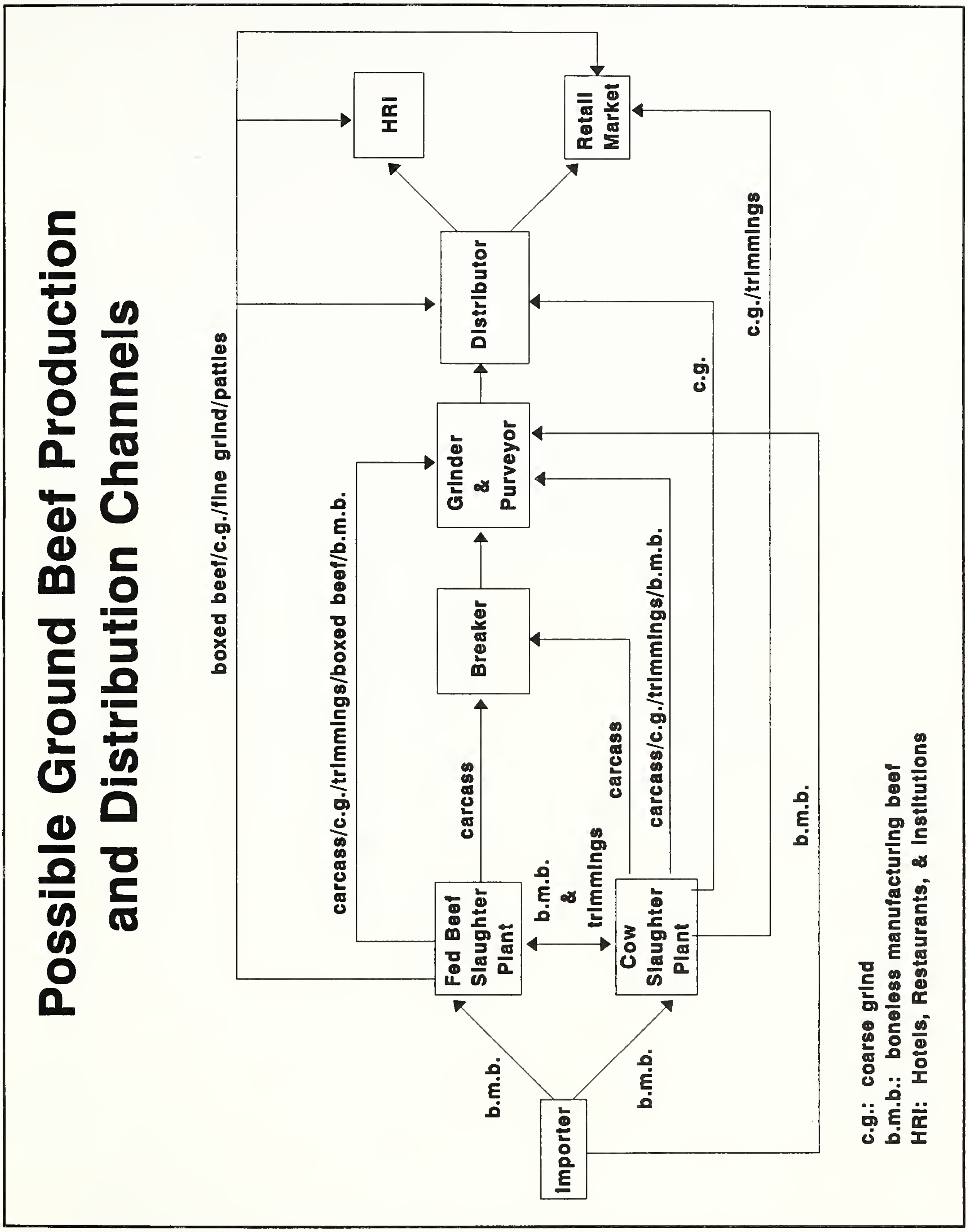
Management Practice	Subgroup	Association with O157
Small herd size[a,b]	Dairy farms	pos, none
Use of computerized feeders[a]	Dairy farms	pos
Irrigation of pastures with manure slurry[a]	Dairy farms	pos
Feeding of whole cottonseed[a,c]	Dairy heifers and cows	neg, neg
Feeding of milk replacer[b,c]	Dairy calves	neg, none
Feeding of ionophores[b,c]	Dairy calves	pos, none
Grouping of calves prior to weaning[b,c]	Dairy calves	none, pos
Sharing of unwashed feeding utensils among calves[c]	Dairy calves	pos
Feeding of oats in starter ration[c]	Dairy calves	pos
Feeding of grain during first week of life[b,c]	Dairy calves	none, pos
Feeding of clover as first forage[c]	Dairy calves	neg

* Many other management factors have been tested for association with O157; only those listed were found to have statistical significance at $p \leq 0.10$.

pos = positive association, i.e., management practice is associated with increased O157 prevalence
neg = negative association, i.e., management practice is associated with decreased O157 prevalence
none = no association

[a] Hancock et al., 1994
[b] Hancock et al., 1993b
[c] Garber et al., 1994

Figure 1


Possible Ground Beef Production and Distribution Channels
Importer
b.m.b.
b.m.b.
Fed Beef Slaughter Plant
Cow Slaughter Plant
b.m.b. & trimmings
carcass
Breaker
carcass
Grinder & Purveyor
carcass/c.g./trimmings/boxed beef/b.m.b.
carcass/c.g./trimmings/b.m.b.
b.m.b.
Distributor
boxed beef/c.g./fine grind/patties
c.g.
c.g./trimmings
HRI
Retail Market
c.g.: coarse grind
b.m.b.: boneless manufacturing beef
HRI: Hotels, Restaurants, & Institutions

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Fort Collins, Colorado 80521

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Baltimore Boulevard
Beltsville, MD 20705-2351